Performance boosters from Power Services (white bottle) and Stanadyne are flanked by products from Biobor, Star brite, Racor, and ValvTect. Only the biocides proved effective at beating bacteria and fungi.

Biocides vs. Bugs

PS *testers dive into diesel additives test.*

Whenever sailors talk about dirty diesel, advice springs forth regarding the best type of filter, the best stabilizing additive for long-term storage, the best additive for cleaning the tank, and sometimes, the suggested biocides for killing the bacteria and fungus that commonly infect diesel tanks. Advice against certain additives is also common, as are products that claim to cure "tank algae," even though they have no real proof of effectiveness.

It is all very confusing. What is certain is that we need clean fuel to keep our engines running smoothly, and to keep fuel clean, it helps to know how it got dirty in the first place.

Dirty fuel itself is pretty rare in the United States, at least as it leaves the refinery. Heavy-duty trucks ply our highways reliably with very few filtration problems, day-in and day-out. Diesel fuel, as produced in the refinery, has some inherent chemical instability and can polymerize and form sludge in the presence of oxygen. This can also happen in airtight storage, although to a lesser extent.

To reduce these problems, the conventional wisdom and common practice is to maintain storage tanks completely full and to treat them with the storage additive that contains chemicals to inhibit this polymerization. These additives are quite effective and can extend a storage life of diesel fuel to several years; however, they are not perfect, and a certain amount of sludge formation is to be expected. If this is the only mechanism of sludge formation, the buildup will be easily managed by filtration and fuel polishing (routinely cycling fuel through a filtration system).

Biological contamination is another matter. Recreational boats don't operate like trucks; they often stay put for months at a time in a warm, humid environment. Backup generators and fuel storage depots face similar extended non-use cycles. Metal working fluids (oil/water mixtures) also circulate in a warm, open environment. All of these are subject to biological infection, and much of the research concerning fuel biocides is aimed at resolving these types of industrial problems.

INSIDE THE FUEL TANK

Diesel fuel biodegrades easily. Given the presence of a small amount of water and exposure to bacteria and fungal spores—found in the fuel itself or, more rarely, introduced from the atmosphere—substantial amounts of biomass form amazingly fast. Only a trace of water is required, free or emulsified. Although true condensation inside a fuel tank is very limited under most circumstances, fuel almost inevitably absorbs small amounts of water.

Through the course of a sailing season—with its cyclical variation between daytime high temperatures and nighttime lows—this water will eventually precipitate inside the tank. Add warm weather and gentle agitation as the boat rocks, and you have an effective incubator for bacteria and fungi.

A big part of the battle against bugs then, is eliminating water from fuel. A water-separating filter is the most common defense against water. A variety of additives claim to help disperse or demulsify water in diesel fuel, helping to aid in water filtration. This test looked solely at the ability of additives to kill bacteria and fungi. A powerful defense against fuel contamination of any kind, as we have stated many times, is an easily accessible fuel tank with large inspection ports for cleaning ("Diesel Fuel Tank Replacement," May 2007).

At the onset of an infection, filtration seems to help. The filters will catch the larger clumps of bacteria, but individual organisms are much smaller than the finest filtration. Bacteria and spores measure only 0.1 microns, so even ultra-fine filters rated at 1-micron (most secondary filters on small marine diesels are no finer than 2 microns), pass enough organisms to continue the infection.

Eventually, substantial biomass accumulates inside the tank, and either a change in fuel chemistry or vigorous mixing on a rough day will knock some of it loose, and the sailor discovers his filters clogged far sooner than he expected. Often, it happens at the worst possible moment—a good argument for a twin-filter system with a pressure gauge for monitoring filter status and a valve that lets you switch filters on the fly.

Biological growth is instantly recognizable as a brown, gray, or black mucous-like substance that coats the inside of the tank, fuel lines, and filter elements. If the sludge collecting in your filter consists of fine particulates, rust, or tarry material that leaves a black, sticky residue on your fingers, you're probably not looking at biological contamination. You may need to clean your tank, and you are a good candidate for fuel filtration

PS VALUE GUIDE DIESEL ADDITIVES

Manufacturer		BIOBOR JF ✓	RACOR BIOCIDE ✓	STANADYNE	STAR BRITE ✓	STAR BRITE	VALVTECT ✓
Product		Hammonds	Racor	Performance Formula	Biodiesel	Star Tron Diesel	Bioguard
Price*		$12	$15	$7	$21	$20	$20
Quantiy		8 oz.	16 oz.	16 oz.	16 oz.	16 oz.	16 oz.
Shock dose		.025 oz./ gal.	.025 oz./ gal.	.27 oz./ gal.	.03 oz./ gal.	.03 oz./ gal.	.03 oz./gal.
Maintenance dose		.0125 oz./ gal.	.0125 oz./ gal.	.27 oz./ gal.	.017 oz./ gal.	.03 oz./ gal.	.017 oz./gal.
Shock cost		4¢/gal.	2¢/gal.	12¢/gal.	4¢ /gal.	4¢ /gal.	4¢ /gal.
Maintanace cost		2¢ /gal.	1¢ /gal.	12¢ /gal.	2¢ /gal.	4¢ /gal.	2¢ /gal.
Claims		Biocide	Biocide	Better performance	Biocide	Disperse bacteria, ease filtration	Biocide
Registered pesticide		Yes	Yes	No	Yes	No	Yes
Phase (Solubility)		Oil, thick, mix with diesel before adding.	Water/oil emulsion	Oil	Water	Water	Oil
Microbe count/ "A" Culture**	24 hr.	10,000	10,000	1,000	0	100	100
	48 hr.	10,000	10,000	1,000	0	1,000	100
Microbe count/ "B" Culture	24 hr.	0	0	10,000	2,000	10,000	2,000
	48 hr.	0	0	10,000	2,000	10,000	2,000

✓ Recommended

*Average retail price. **Two control samples, one diesel and one biodiesel, showed biomass counts of 10,000 at all sample periods.

and stabilizing additives, but bugs are not your main problem. However, if the material is slimy—in severe cases slimy stalactites of goo will hang from the filter—you have a biological infection.

BIOCIDES

A commonly prescribed cure for a serious microbial infection is to kill it with biocides. Unlike a sinus infection that will pass as your body rallies, a substantial biological infection of your fuel tank is unlikely to fix itself through filtration alone. But killing the bugs is only half the battle. The sudden release of dead bacteria from the surfaces of the tank can raise other problems. This surge of slime clogs filters, causes fuel starvation, or has other potentially harmful results.

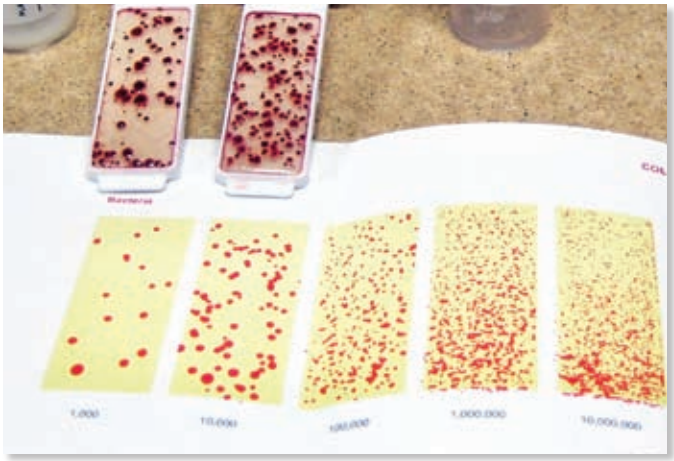
In a badly infected fuel tank, the dead bodies will probably have to be mechanically removed, either through filtration or a thorough tank cleaning and fuel change. There are many chemicals that claim to be able to clean your tank or to help keep your fuel clean, but the mass of solids present in a badly infected tank can far exceed the safe application of this approach. So, if you do decide to attack a severely infected tank with a biocide, don't do it right before you're planning a tank-agitating voyage unless you plan to follow it with aggressive filtration, a fuel change, or tank cleaning.

Magnetic bug killers receive considerable anecdotal press. *Practical Sailor* tested two widely available units—De-bug and Algae-X—in the April 15, 1997 issue and concluded they had no observed effect on microbial growth. As a part of the 1997 trial, a biocide was also tested for comparison, and this was found to be very effective.

Any manufacturer claiming its product is a biocide must register that formulation with the U.S. Environmental Protection Agency (EPA) as a pesticide or anti-microbial. As you might imagine, this is an involved and strictly regulated process. As a result, there are far fewer formulations than there are products on the market. Most products piggy-back on existing registrations, and in our research, we found that the products readily available to boaters have one of four types of active ingredients, and these ingredients vary in their solubility in fuel and water: dioxoaborinanes, dithiocarbamates, morpholine and compounds, and thiocyanates. (See table, page 22.) Products within any registration are virtually the same and can be expected to deliver similar results.

The conventional thought is that water-soluble products give a better quick-kill, as they enter the phase where the micro-organisms live. Fuel-soluble products may be better for maintenance dosing, as they blend easier with the fuel and better reach all portions of the fuel system. While these subtleties are important when treating huge industrial storage tanks, they may not apply to recreational boats. All of these products have some solubility in both water or oil, and should mix fairly well in a boat, which has a relatively tiny tank (compared to industrial tanks) with contents that are being sloshed around.

Biocides are pesticides and as such, aren't good for you. Users should carefully read the Material Safety Data Sheets (available online) for these products before use. The Occupational Safety and Health Administration (OSHA) regulates their use in metal working fluids where workers are likely to be continuously exposed to vapors and mists. Infrequent users are advised to wear gloves when handling the concentrate. It is the concentrated biocide, not the resulting diesel fuel mixture, that is potentially harmful.



BIOCIDES USED TO COMBAT BACTERIA IN DIESEL		
PRODUCT	ACTIVE INGREDIENT	WATER OR FUEL SOLUBLE
Bio-Bor JF	Dioxaborinanes	Fuel
Ako-Nobel/ALCO Aquatreat DM-30* Pri-Ocide* ValvTect Bioguard Star brite Bio Diesel FPPF Kill-em*	Dithiocarbamates	Water
Power Service Bio-Kleen*	Morpholine and compounds	Water and Fuel
Racor Bioguard	Azole / Thiocyanates	Water

* Not tested; Star brite Star Tron is not a biocide and so is not listed here

The control samples were tested after being shaken (left slide) and not shaken (right slide) to observe the effect. Both cultures gave similar results. Four different types of biocide are used to combat bacteria in diesel (table, above right).

HOW WE TESTED

Testing was straightforward: Find some infected fuel and see what killed bugs and what didn't. Absolute victory is the aim; as any survivors are likely to repopulate the tank. The contaminating organisms were collected from two diesel fuel tanks. These were further conditioned to ultra-low sulfur fuel oil over a period of three weeks and labeled as "Culture A" and "Culture B." Examination under a microscope showed a variety of bacterial and fungal species in each. Although some people speak of "algae" in their fuel, the critters typically responsible for diesel fuel degradation are fungi or bacteria, which can live on a diet of hydrocarbons without any light for photosynthesis.

The contaminated test fuel was ultra-low sulfur from a major refiner. Differences in biodegradability between different refinery batches are relatively minor. However, switching from one fuel source to another can sometimes cause all or a portion of the biomass to become dormant and slough-off the tank walls. It is as if the favorite lunch special has suddenly been pulled from the menu.

For one of our controls, we included biodiesel fuel. Our sample was typical of what is available in the market. Independent research suggests that bio-degradability of biodiesel should be comparable to ultra-low sulfur diesel, but our results were quite different; we found that the bugs grew nearly 10 times as fast in the biodiesel mixture, even though they were not bugs conditioned to or specifically chosen for that ability. Growth then suddenly stopped, for no apparent reason. This behavior has been observed by other researchers and is not well understood.

After the conditioning period, test tubes were prepared with 10 milliliters of contaminated water, 140 milliliters of diesel fuel or B-20 mixture, and the manufacturer recommended dose of biocide. The tubes were inverted three times to simulate the minor amount of mixing present as a tank is filled or the boat is moved, but they were not vigorously shaken. Control tubes containing each infected diesel and B-20 sample were tested for the presence of bacteria to establish a baseline for untreated fuel. Relative microbial counts of control and test cultures were determined through the use of dip-slides prepared to be reactive to both bacteria and fungus. All slides were incubated at 80 degrees, and observations were made at 12-hour intervals.

BIOBOR JF

Texas-based Hammond Technical Services serves everything from the pipeline to military markets. Biobor JF is promoted as effective in diesels and jet fuels, as well as light fuels and transmission oils. Hammond also sells a Hum-Bug Detection Kit to check for fungi or bacteria. Its registered biocide is a dioxaborinane, the same as Star brite Bio Diesel. This is a thick product that should be mixed with diesel before adding to your tank.

Bottom line: Biobor was one of two products that allowed no microbe growth the Culture B. This is a Recommended product.

DIESEL BIOCIDE (RACOR)

A division brand under the prominent filter-maker Parker, Racor markets a biocide that proved as effective against group "B" culture as the Biobor JF. The main difference between it and the Biobor is the active ingredient. Racor uses a thiocyanate that is soluble in water. It also is slightly less expensive than the Biobor. The Racor biocide is an emulsion, soluble in both water and oil.

Bottom line: Like the Biobor, this Recommended product allowed no microbe growth in Culture B, but was ineffective against Culture A.

STANADYNE PERFORMANCE FORMULA/ POWER SERVICE PLUS CETANE BOOST

Curious to see whether they had any effect on biomass, we included these two performance-enhancing products. They make no biocide claims, but they do claim to bring water out of suspension. Stanadyne is a well-known maker of fuel system parts as well as additives. Power Service Plus offers a variety of fuel additives.

Bottom line: Surprisingly, Stanadyne (shown in table) had some effectiveness

against the microbes in the Culture A and none on Culture B. The Power Service Plus formula had no detectable effect on either culture. In the all-or-nothing war against microbes, neither is much help, nor do they claim to be.

STAR BRITE

We tested two Star brite products, Star brite Bio Diesel and Star Tron Diesel. Only the Bio Diesel product contains a pesticide, a thiocarbamate, the same type found in ValvTect Bioguard. Star Tron is supposed to work by dispersing sludge and water, making it easier to filter out contaminants that can promote biological growth. Again, we did not test for this.

The main difference between the ValvTect Bioguard and the Star brite Bio Diesel is that the ValvTect is oil soluble, while the Star brite blend is considered water soluble. Although Star Tron Diesel has no pesticides, it held microbes in Sample A at bay for 24 hours.

Bottom line: The Star brite Biodiesel biocide allowed no growth in Culture A and is a Recommended product. The Star Tron Diesel is not a bug killer, it is a fuel conditioner and dispersant.

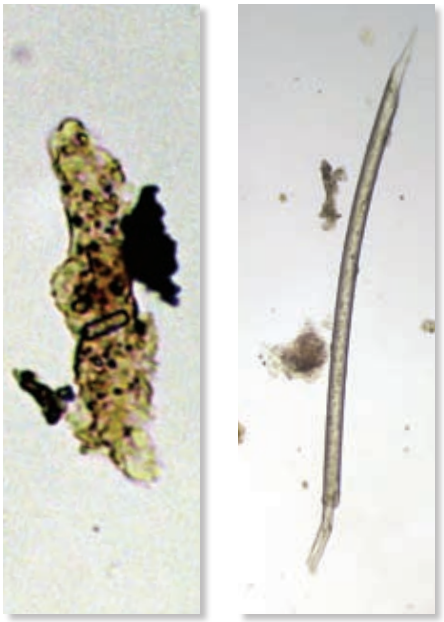
VALVTECT BIOGUARD

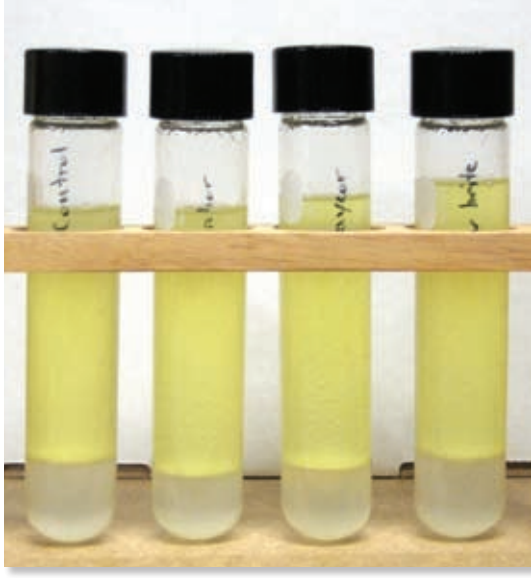
ValvTect is a subsidiary of RPM International (also makers of Rust-Oleum) that specializes in fuel additives. It claims to be the nation's leading supplier of fuel additives to the marine industry. Bioguard features an oil-phase additive that includes the water-soluble active pesticide ingredient, di-thiocarbamate. This appears to be the most common pesticide type used in diesel additives on the marine market.

Bottom line: ValvTect is readily available and worked well on our A culture. It is a Recommended product and compares very closely to the Star brite Bio Diesel.

CONCLUSIONS

Like any antibiotic, it seems the cure depends on the sickness. In Culture A, we found that carbamate-based biocide consistently performed very well. Oddly, Star brite Bio Diesel and Stanadyne Performance Formula were more potent in Culture A than other registered biocides. Like many home-remedies, it seems they simply had the right stuff for this infection. In Culture B, the borinane and thiocyanate formulations shone, but not the other biocides, and not the general performance additives. So, is the cure for your infection amoxicillin or bacitracin? It depends on the infection.





Under the microscope, bacteria (left) and fungi (right) in fuel are evident. But even a significant colony in our control sample (left-hand test tube, above) is invisible to the naked eye.

The most consistent users of these biocides—airports—typically pick a biocide and stay with that one product. However, the results of our testing suggest that changing additives twice a year is a viable defense as well, perhaps more effective. The required maintenance dosage and price of biocides is very low compared to the performance additives. It would be most economical to use a borinane (Biobor) half of the year and a thicarbamate (Star brite Bio Diesel or ValvTect BioGuard) the rest of the year. Any formulation of the same chemistry as these would also get our recommendation.

Because the growth of biomass is dependent on some water accumulation, fuel polishing and the use of water-separating additives (demulsifiers) are expected to be a helpful in prevention. This is not because the equipment and products remove bacteria or kill them: Filtration removes fine particles and makes fuel/water emulsions less stable, and separation additives destabilize emulsions making water removal easier. Emulsions generate enormous surface area helping to spread bugs. Without water and fuel/water emulsions, the tank becomes a poor environment for microbial growth. Fuel polishing doesn't eliminate bacteria, it reduces susceptibility. The dual-filter fuel polishing/filtration system, Filter Boss (*www.filterboss.com*) on one of our test boats, works flawlessly, although a DIYer can build a similar system for less. A comparison of similar off-the-shelf fule/polishers is in the works.

For more on tank cleaning and combatting fuel bugs, check out the "Also with this article" box next to the online version of this article at *www.practical-sailor.com*. And please properly dispose of any treated fuel or water removed from your tank.

CONTACTS

BIO-BOR JF, 800/582-4224, www.hammondscos.com

POWER SERVICE, 800/643-9089 www.powerservice.com

RACOR, 800/344-3286, www.racor.com

STANADYNE, 860/525-0821, www.stanadyne.com

STAR BRITE, 800/327-8583, www.starbrite.com

VALVTECT 800/728-8258, www.valvtect.com